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LAND MANAGEMENT PRACTICES AFFECTING INCOME ON HOYTVILLE SOIL

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SUMMARY

Hoytville soil is highly productive when adequately drained. This conclusion is based on a detailed study of crop yields and production practices found on 100 farms in Wood County, Ohio, for 1955 and 1956.

For the two-year period, the best-drained group of farms produced 28 percent more corn, soybeans and oats and 12 percent more wheat per acre than the poorest drained group.

Corn yields were affected more by drainage than by any other single factor. Average annual value of the crops from a rotation of corn, soybeans, oats and meadow was calculated to be about $9.80 per acre more from the best drained than from the poorest drained land. However, a small amount of this difference might be attributed to better management. If all of the additional net income were capitalized at five percent, a landlord owning poorly drained land could afford to invest about $70 an acre in additional drainage installations. An owner-operator might be able to justify a higher investment.

Profits from fertilizer were influenced by adequacy of drainage. Above average drained land produced greater profits from a given amount of fertilizer than below average drained land. Except on the best drained farms, applications of fertilizer on corn did not pay when all of the fertilizer was charged against the crop to which it was applied. Since Hoytville soil is high in natural fertility, response from fertilizer usually was small unless other growth-producing factors were favorable.

Farmers on Hoytville soil found it difficult to follow a given rotation. Few were able to avoid deviations in some years. Most of them attributed this situation to unfavorable weather at time of planting and to government control programs for corn and wheat. The cropping programs followed had little effect on the yields of soybeans, oats, or wheat. But corn yields were about 10 percent higher when a mature meadow was plowed under instead of a green manure crop.

Net income figures showed that the most profitable rotation was corn, soybeans and wheat with a green manure crop grown in the wheat and plowed under the following spring for corn. The following rotations ranked next in profitability and produced about the same net income per acre: corn, corn, soybeans, wheat and meadow; corn, soybeans, soybeans, wheat and meadow; and corn, soybeans, wheat and meadow. Rotations with oats were not as profitable as rotations with wheat.

When hay was harvested and sold for $15 a ton, net income was about the same as when no meadow growth was harvested as hay or pasture. Hay would have to be sold for about $27 a ton at the farm to make a rotation of corn, wheat and two years of meadow as profitable as corn, soybeans, wheat and one year of meadow.

Most farmers on Hoytville soil raise a high percentage of grain crops because markets for hay are generally poor and only enough livestock is kept to consume a few acres of forage. About 45 percent of the farmers reported no livestock of any kind.

Although a high proportion of grain crops have been raised on Hoytville soil during recent years, yields would indicate that productivity has not declined greatly For example, during the 30-year yeriod, 1928-57, corn yields for Wood County increased at an average rate of .80 of a bushel per year. For the State of Ohio, the annual increase averaged .89 of a bushel per acre for the same period. For the state as a whole, higher corn yields may be partially due to a reduction in the acreage grown on the poorer land.

OBJECTIVES

This study had two major objectives. The first one was to determine how various land management practices affect crop yields on Hoytville soil[1]. The second objective was to determine the relative profitability or economic effect of using the different crop producing practices.

Hoytville soil makes up about 1,300,000 acres of land in northwestern Ohio, southern Michigan and northeastern Indiana. About three-fourths of this total acreage is located in the Lakebed area of northwestern Ohio. Most of the Hoytville soil in Ohio is located in the following counties: Wood, Putnam, Henry, Van Wert, Sandusky, Seneca, Hancock and Paulding.

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[1]In this study, Hoytville soil generally means Hoytville clay. However, it also includes a small percentage of Hoytville clay loam and silty clay loam.

Hoytville soil originated from glacial till which was modified by lake deposits. Consequently, this soil is generally found on flat areas which have poor natural drainage. The top seven inches of soil are a very dark gray clay which is sticky and plastic when wet and hard when dry. The subsoil, to a depth of about 36 inches, is a mottled gray and yellowish brown clay that is somewhat heavier and more plastic than the surface soil.

Drainage through tile is slow because the clay content ranges from about 40 to 50 percent. Surface drainage also is poor because of level topography. The supply of phosphorous is generally rated low to medium, but potassium is usually high. Usually little or no lime is needed. Organic matter is relatively high.

METHOD OF STUDY

Data on land use, crop yields, fertility practices, drainage and livestock numbers were collected on 103 farms for 1955 and 101 of these same farms for 1956. Most of these farms were located in the southern part of Wood County.

This study was confined to Wood County because this was the only large area where the extent and location of Hoytville soil had been mapped by standard soil survey procedure. Without this information, farms having the desired soil type could not have been selected accurately. Although large areas of Hoytville soil exist in other parts of northwestern Ohio, maps showing the specific location of this soil were not available. By confining this study to a relatively small area, variations in yields due to differences in rainfall were minimized.

Farms studied included only tracts of land which had more than 90 percent Hoytville soil. County ownership maps showed 255 units that had the desired soil type and size for this study. But only 103 tracts of land were actually studied. In selecting the sample farms, the first step was to stratify the 255 tracts of land into the following size groups: 60-99 acres, 100-139 acres, 140-179 acres, 180-219 acres, and 220 or more acres. All of the farms which had 180 acres or more were included in the study because there were only a few farms in these groups. A random sample was drawn from the more populous classes to complete the list of farms to be studied.

Crop yields were determined from sales records, storage capacities and farmers' estimates. These yields were used in calculating the profitability of using various amounts of fertilizer and different crop rotations and to determine additional expenditures that could be justified in improving drainage.

Drainage ratings were determined on the basis of these factors: spacing and age of tile lines installed; control of surface water by natural topography or surface drainage, as evidenced by ponded or standing water; farmer's opinion of whether his farm was better or poorer drained than neighboring tracts; and other indications such as timeliness of field operations.

DESCRIPTION OF FARMS STUDIED

Land Use. Acreages of various crops are shown in Table 1 for 100 farms on which continuous records were obtained for 1955 and 1956 and for which no changes in size occurred during this 2-year period. From 1955 to 1956, no marked changes occurred in the combined arceages of oats and wheat grown. However, the acreage of meadows declined slightly during this period. At the same time, a corresponding increase occurred in the acreages of corn and soybeans harvested. Percentage of meadows raised was not quite the same for all drainage groups. Fifteen percent of the rotated land was used for meadows on the below average drained farms compared with 19 percent for the farms having average or better than average drainage (Table 2).

Crop Yields. Average crop yields for all farms are shown in Table 3. For the 2-year period, the best drained group of farms averaged 28 percent more corn, soybeans and oats and 12 percent more wheat per acre than the poorest drained group.

From the standpoint of rainfall, the 1955 planting season was just about opposite the one for 1956. During April and May, 1955, total rainfall averaged 1.68 inches below normal, but in 1956 rainfall was 2.45 inches above normal for the same period[2]. However, yields of corn on the best drained farms averaged about the same for 1956 as 1955. But on the poorest drained farms, yields of corn averaged nine bushels less in 1956 than in 1955.

Livestock Numbers. Only a small amount of livestock was kept on the farms studied. On about 45 percent of these farms, no livestock of any kind was reported. Six farms had 10 or more dairy cows, and 7 farmers reported beef breeding herds of 10 or more cows. Fifteen farmers marketed more than 50 fat hogs annually and 10 sold more than 25 head of fat cattle.

The main reasons given by farmers for not raising more livestock

[2]For Bowling Green which was the nearest weather station.

included the following: grazing animals pack the soil and therefore make it difficult to prepare a satisfactory seedbed for corn and soybeans; on many farms, more livestock would require heavy investments

Table 1.—Land Use by Drainage Groups for 100 Farms Having Hoytville Soil, 1955-56

Land use	Average acreage per farm		
	1955	1956	1955-56
Below average drainage (27 farms)			
Corn	35	38	36
Soybeans	33	33	33
Oats	21	16	19
Wheat	16	21	18
Meadow	19	16	18
Rotated crops	124	124	124
Permanent pasture	0	0	0
Woods and miscellaneous	16	16	16
Total	140	140	140
Average drainage (35 farms)			
Corn	37	39	38
Soybeans	29	36	33
Oats	18	16	17
Wheat	17	19	18
Meadow	29	20	24
Rotated crops	130	130	130
Permanent pasture	1	1	1
Woods and miscellaneous	12	12	12
Total	143	143	143
Above average drainage (38 farms)			
Corn	39	42	40
Soybeans	34	37	36
Oats	20	16	18
Wheat	22	25	23
Meadow	30	25	28
Rotated crops	145	145	145
Permanent pasture	1	1	1
Woods and miscellaneous	12	12	12
Total	158	158	158

Table 2.—Percentage of Rotated Crops by Drainage Groups on 100 Farms Having Hoytville Soil, 1955-56

Crop	Drainage rating		
	Below average	Average	Above average
Corn	29	29	28
Soybeans	27	25	25
Oats	15	13	12
Wheat	14	14	16
Meadow	15	19	19
Total	100	100	100

Table 3.—Average Crop Yields by Drainage Groups for Farms Having Hoytville Soil, 1955-56

Crop and drainage rating	1955	1956	Average 1955-56
	bushels	bushels	bushels
Below average drainage			
Corn	65	56	60
Soybeans	26	24	25
Oats	53	42	47
Wheat	34	32	33
Average drainage			
Corn	69	65	67
Soybeans	29	27	28
Oats	57	48	52
Wheat	35	32	33
Above average drainage			
Corn	77	78	77
Soybeans	33	31	32
Oats	65	55	60
Wheat	39	36	37
All farms			
Corn	71	68	70
Soybeans	30	28	29
Oats	59	49	54
Wheat	36	34	35

in new buildings and fences; and on the larger farms, labor demands for the care of livestock interfere with the planting of spring crops. It should also be noted that fairly satisfactory incomes were obtained on many of these farms from a cash-grain system of farming.

CROP YIELDS AND RAINFALL DISTRIBUTION FOR 1955-56

Yields indicate that 1955 and 1956 were slightly better than average crop years. For 1955, yields of corn, soybeans and wheat were calculated to be about 8 percent above normal and oats 22 percent[3]. For 1956, yields of corn averaged about seven percent above normal. But yields of soybeans, oats and wheat were only four percent above normal.

Monthly distribution of rainfall and deviations from normal at Bowling Green are shown in Table 4 for the 2-year period. This

Table 4.—Distribution of Rainfall at Bowling Green, Ohio, 1955-56

Month	Rainfall in inches		Deviations from normal	
	1955	1956	1955	1956
January	1.45	1.25	— .84	—1.04
February	1.74	2.56	— .15	+ .67
March	3.13	3.29	+ .03	+ .19
April	3.34	4.11	+ .22	+ .99
May	1.79	5.15	—1.90	+1.46
June	.55	4.42	—3.16	+ .71
July	7.54	2.84	+4.00	— .70
August	2.64	5.98	— .05	+3.29
September	1.91	1.06	—1.00	—1.85
October	4.35	.63	+1.76	—1.96
November	4.08	1.67	+1.67	— .74
December	.43	2.10	—2.11	— .44
Total	32.95	35.06	—1.53	+ .58

weather station was the nearest one which had rainfall data for a number of years. Although distribution of rainfall for 1955 and 1956 was considerably different during the planting and growing season, yields for all crops except oats averaged about the same for both years.

An analysis of crop yields and rainfall distribution in Wood County

[3]Normal grain yields for Wood County were estimated by use of linear equations for the 30-year period, 1928-57, for corn, oats and wheat and for the 18-year period, 1940-57, for soybeans.

for a 30-year period showed that high corn yields were associated with a rainfall pattern that was below normal in April and May and slightly above normal during the growing season (Table 5). Low corn yields usually occurred when rainfall was above normal during the planting season and below normal during the growing season. Above normal rains in April and May may have reduced yields because of late plantings and below average stands. High soybean yields were associated with below normal rainfall at planting time and above normal rainfall during July and August. High oat yields usually occurred when rainfall was below normal in March and April because plantings could be made early in these particular seasons. High wheat yields were associated with dry seasons.

EFFECTS OF CERTAIN FACTORS IN CROP PRODUCTION

Factors in crop production which were studied included fertilization, degree of drainage, stand or plant population, time of plowing for corn, livestock numbers, tenure status of operator and method of seedbed preparation for wheat. The effect of different cropping programs on yields is discussed in a separate section.

Table 5.—Monthly Deviations from Normal Rainfall for Selected Years of High and Low Grain Yields, Wood County, 1928-1957[1]

Month	Corn		Soybeans[2]		Oats		Wheat[3]	
	Low yield years	High yield years	Low yield years	High yield years	Low yield years	High yield years	Low yield years	High yield years
January	+ .36	—.80	— .41	— .41	+ .56	—.54	— .26	—.91
February	— .43	+.20	— .69	+ .33	— .27	—.35	— .28	—.89
March	— .60	+.10	.00	— .27	— .38	—.63	— .38	—.80
April	+ .70	—.22	— .33	+ .11	+1.43	—.64	+ .55	—.50
May	— .05	—.94	+ .76	+ .74	+ .61	—.54	— .16	—.67
June	+ .58	+.14	+ .97	— .96	+ .03	—.25	+1.01	—.59
July	— .97	+.59	—1.02	+ .56	— .65	—.35	— .76	—.30
August	—1.26	—.13	— .88	+1.15	— .70	+.14	+ .40	—.34
September	+ .22	—.61	— .20	—1.05	+ .18	—.75	+ .39	—.37
October	+ .25	—.36	+ .10	— .10	— .83	—.72	— .04	—.64
November	— .65	—.08	— .26	— .20	— .58	—.07	+ .36	—.65
December	— .49	—.84	— .38	—1.07	—1.08	—.80	— .30	—.75

[1]Based on rainfall data for Bowling Green, Ohio.

[2]Soybean yields are for the period 1940-57; no county data available before 1940.

[3]Rainfall data from August to December for wheat is average for the years in which the respective crops were planted.

Although fertilizer used on the farms in this study was of many different analyses, rates are given in terms of 3-12-12 which was the analysis most commonly used. Other analyses were adjusted to the 3-12-12 basis by assuming that each nutrient element had the same effect on yields. Thus, 90 pounds of 3-18-9, or 75 pounds of 12-12-12, or 108 pounds of 5-10-10 were considered equal to 100 pounds of 3-12-12 because each of these combinations contains 27 pounds of plant food. It was recognized that these fertilizer elements were not exact substitutes for each other, but this method of adjustment was considered practical where similar proportions of the various elements were used.

For statistical purposes, drainage ratings were given numbers as follows: below average, 1; average, 2 and above average, 3. Some tile had been installed on all farms in this study, but in some cases, the normal life expectancy of the original tile had expired. Very frequently the original tiling had been at 100 foot spacings, with subsequent addition of laterals between the originals. The commonly accepted ideal was a tile lateral every 50 or 60 feet. In some cases, a recent installation of laterals was made but usually this was considered a replacement rather than an addition to existing tile.

A common practice was to plow at right angles to tile lines, rather than parallel to them. The practice of digging channels to permit runoff of ponded water also was followed by some farmers. However, planned control of surface water by other means was not common. Shaped and graded waterways and land leveling were rarely used although interest in them seemed to be increasing.

Crop yields were determined for different fertilizer applications and degrees of drainage by a combination of sorting and regression. Use of both of these methods gave two yield figures for each fertilizer application and drainage level. Figures in Table 6, 9, 10, and 11 are averages of the yields calculated by these two methods. Averages were used because they were in closer agreement with the original data in Table 3 than either set of yields taken individually.

CORN

Corn was the most important crop on the farms in this study, occupying about 29 percent of the rotated cropland. In 1955, yields ranged from 32 to 120 bushels per acre, the average yield was 71 bushels, and about two-thirds of the yields were between 58 and 85 bushels per acre. In 1956, the range extended from 43 to 115 bushels per acre. The average yield was 68 bushels, and about two-thirds of the yields were between 52 and 83 bushels per acre.

Table 6.—Expected Yields of Corn for Selected Rates of Fertilization and Levels of Drainage on Hoytville Soil (Based on the Yield Experience of 103 Farmers in 1955 and 101 in 1956)

Year	Fertilizer used, lbs. per acre[1]	Drainage rating		
		Below average	Average	Above average
			(bushels per acre)	
1955	0	68	69	69
	150	66	69	73
	300	64	69	77
	450	63	69	82
1956	0	54	62	66
	150	55	64	71
	300	57	66	76
	450	58	68	82
Average 1955-56	0	61	65	67
	150	61	66	72
	300	61	67	77
	450	61	68	82

[1]Fertilizer is expressed in pounds of 3-12-12 analysis.

The rainfall distribution table for Bowling Green (Table 4) indicates that 1955 was drier than 1956 in May, June and August but also wetter in July, October and November. The dry period in May and June of 1955 resulted in timely plowing and planting of crops so that yields were high. The same condition also led in some cases to dry seedbeds and poor germination so that stands were on the average poorer than in 1956. Excess rainfall in the spring of 1956 resulted in delays in planting which frequently reduced yields, but the stands of corn were generally better in 1956 than in the previous year.

FERTILIZER AND DRAINAGE

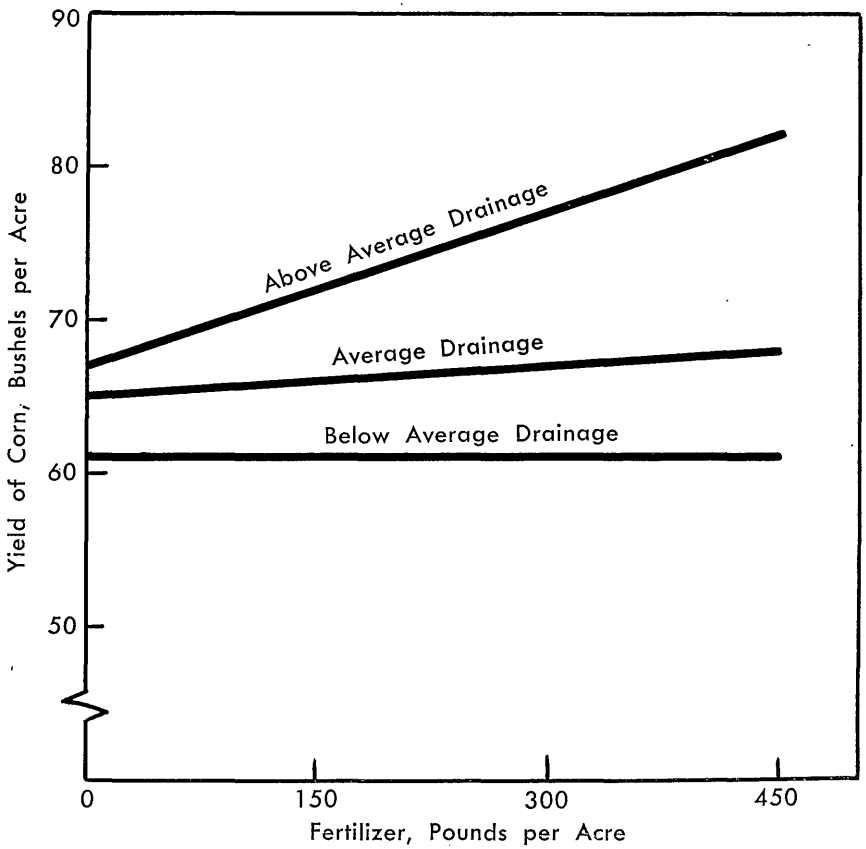
Use of fertilizer in production of corn was widespread among farmers contacted in this study, but it was by no means universal. About one farmer in six used no commercial fertilizer on corn. The most common rate of fertilizer use was 200 pounds of 3-12-12 per acre, while 500 pounds or more were applied by 9 farmers in 1955 and by 16 in 1956.

Important effects of tile drainage were reduction of the variation in yields due to yearly differences in weather and the easing of labor

peaks by making weather less of a restriction in field work. In addition, the drainage rating influenced the effectiveness of fertilizer.

On above average drained land, a 15-bushel increase in corn yield was associated with applications of 450 pounds of fertilizer (Table 6 and Figure 1). Such a response made fertilizer use profitable, even when the entire application was charged to the corn crop. Figuring corn at $1.20 per bushel and fertilizer at 2½ cents per pound, $11.25 worth of fertilizer per acre gave a yield increase worth $18.00.

On land with average drainage, the corn yield response to 450 pounds of fertilizer was only 3 bushels. This amount of increase was



Source: Table 6

Fig. 1.—Average Yield Response of Corn to Fertilizer at Three Levels of Drainage, Hoytville Soil, 1955-56.

not sufficient, at ordinary price relationships, to justify the use of fertilizer.

On the farms with below average drainage, the average of two years data showed no increase in corn yield associated with application of any amount of fertilizer.

When no fertilizer was used, above average drained land produced an average of six bushels more corn per acre in 1955 and 1956 than below average drained land. But when 450 pounds of fertilizer was used, this difference increased to 21 bushels. The effects of drainage were more noticeable in a wet planting season like 1956 than in a dry crop year like 1955.

Fertilizer and drainage have independent effects upon the yield of corn but they also have important interactions. The full potential influence of these factors cannot be realized unless both fertilizer and drainage are used together.

STAND OR PLANT POPULATION

For each farm in the study, the stand of corn was rated as poor (1), fair (2), or good (3). Numerical ratings were used for comparison of groups of farms. Stands were better in 1956 than in 1955 with a rating of 2.7 compared to 2.3.

Stand of corn may be a partial explanation of the variation observed in response to fertilizer use in 1955. On average and below average drained land, increases in fertilizer use were associated with poorer stands. It is quite unlikely that the fertilizer caused impairment of stand, for on above average drained land more fertilizer was associated with better stand. A reduced plant population might be expected to result in lower yields. It seems likely that the reduction in yields, where observed to be associated with increased fertilizer use (Table 6), was due to poorer stand rather than to any adverse influence of fertilizer.

TIME OF PLOWING

Only a few farmers plowed all of their corn land in the fall. However, 28 farmers in 1955 and 23 in 1956 raised corn on land of which at least one-fourth had been plowed in the fall. On these farms, fall plowing averaged 48 percent of the corn land for this period. This group of farmers obtained two bushels per acre in 1955 and eight bushels per acre in 1956 more than farmers whose plowing was all done in the spring. Because of the variation in yields within the two groups, the difference between groups was not considered significant[4].

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[4]Not significant at five percent level.

Even though the foregoing figures are statistically not significant, they point in the same direction as research performed at the northwestern substation at Hoytville[5,6].

LIVESTOCK NUMBERS

To determine the effect of livestock on yield of crops, farms having the greatest numbers of livestock were compared with farms which had no livestock. The livestock farms numbered 30 in 1955 and 29 in 1956. Their average livestock population was about 23 animal units per 100 acres or one cow (or equivalent) for about four acres of cropland. These farms had a 2-year average corn yield of 71 bushels per acre, while the 49 farms without any livestock averaged 69 bushels. This small difference could be explained by the difference in drainage of the two groups of farms (Table 7).

Table 7.—Corn Yields with Livestock Farming and without Livestock on Hoytville Soils, 1955-56

Livestock, animal units	Corn yield, bu.[1]	Fertilizer used, lbs. per acre	Drainage rating	Spring plowed, percent	Stand
23	71	270	2.4	91	2.5
0	69	270	2.1	87	2.5

[1]Difference not significant at five percent level. L.S.D.=five bushels.

TENURE OF OPERATOR

Factors related to tenure, such as limitation of capital and willingness to invest for future returns, may have considerable effect on crop yields on Hoytville soil. This was determined by comparison of corn yields on owner-operated and on rented farms. As an average of two years, the yield of corn on owner-operated farms was about five bushels greater than that on rented farms. However, the owner-operated farms had better drainage and used more fertilizer (Table 8). When adjustments were made for these factors, the difference in yields was reduced below the level of significance.

[5]Public Relations Series 46, Ohio Agricultural Experiment Station, August, 1958.

[6]George S. Taylor and W. H. Johnson, "Tillage Studies with Corn on an Ohio Lake Bed Clay Soil." Soil Science Society of America Proceedings, Vol. 20, No. 2, April, 1956, pp. 274-278.

Table 8.—Corn Yields on Owner-Operated and Rented Farms, Hoytville Soils, 1955-56

Tenure	Number of cases	Corn yield, bu.	Fertilizer used, lbs.	Drainage rating	Spring plowed, percent	Stand
Own	95	72	275	2.3	87	2.5
Rent	109	67	260	2.0	88	2.4

SOYBEANS

Soybeans ranked second to corn in acreage on the farms in this study. Soybeans were raised on 94 percent of the farms and (as shown by Table 2) occupied about 26 percent of all cropland. As with corn, yields were quite variable, ranging from 10 to 45 bushels per acre in 1955 and from 15 to 43 bushels in 1956. The average yield was 30 bushels per acre in 1955 and 28 bushels in 1956, with about two-thirds of the yields falling between 23 and 35 bushels. The superior yields of 1955 appear to have been due to the weather, but the effect of weather was somewhat different for beans than for corn (Table 3). Timely plowing and planting and desirable moisture conditions resulted in good stands being reported on more than five-sixths of the farms in 1955, while in 1956, over five-sixths of the farmers reported average or below average stands.

Few farmers applied fertilizer to soybeans. An attempt was made to measure the relationship between soybean yields and rates of fertilizer application on other crops. The users of large amounts of fertilizer averaged three bushels of soybeans more than those who used small amounts. Some of this difference might be attributed to drainage and other factors.

Soybeans on above average drained land yielded about seven bushels per acre more than on below average drained land in each of the two years for which data was gathered. Since soybeans are a shorter season crop than corn and are normally planted later in the spring, delays due to wet weather and slow drying of the soil have less yield-reducing effects for beans than for corn.

Where drainage was poor, 275 pounds of fertilizer per year per acre of cropland increased soybean yields only slightly above a 55-pound application (Table 9). Even where drainage was good, the same amount of fertilizer applied to other crops gave an increase of only two or three bushels of soybeans.

Table 9.—Expected Yields of Soybeans for Selected Rates of Fertilization and Levels of Drainage on Hoytville Soil (Based on the Yield Experience of 97 Farmers in 1955 and 95 in 1956)

Year	Fertilizer used, lbs. per acre per year[1]	Drainage rating		
		Below average	Average	Above average
			(bushels per acre)	
1955	55	26	29	32
	165	26	29	33
	275	26	29	34
1956	55	23	26	29
	165	24	27	31
	275	25	28	32
Average 1955-56	55	24	27	31
	165	25	28	32
	275	25	28	33

[1]This is the average number of pounds of fertilizer applied per acre per year to all crops grown in the rotation. Very little fertilizer was applied directly to soybeans.

Since the cost of fertilizer was charged completely to the crop on which it was applied, fertilizer charges do not appear as costs of soybean production. Therefore, the economics of fertilizer use on soybeans would have to be calculated jointly with other crops in the rotation.

OATS

The small grain crops of oats and wheat tend to compete for the same place in the rotation. When restrictions imposed by weather or government allotments reduce the acreage of wheat, oats tend to increase and the combined acreage is rather constant.

Soybean harvest in the fall of 1954 was delayed by wet weather so that less than the planned acreage of wheat was sowed. As a result, only 84 percent of the farms raised wheat but 92 percent raised oats in 1955. In contrast to this situation, the fall of 1955 was dry enough to permit timely harvest of soybeans and sowing of wheat, and 95 percent of the farms raised wheat but only 79 percent raised oats in 1956.

Yields of oats ranged from 30 to 100 bushels per acre and averaged 59 bushels in 1955, a "good oats year." In 1956, with heavy rains flooding many fields shortly after sowing and with excessive competition from interseeded clover due to the wet season, oat yields ranged from 16 to 90 and averaged 49 bushels per acre.

About 30 percent of the farmers in this study did not use fertilizer on oats. Those who used fertilizer applied about 200 pounds per acre. On below average drained land, 300 pounds of fertilizer increased the 2-year average oat yield only three bushels. But, on above average drained land, this same amount of fertilizer gave an increase of eight bushels in 1955 but only three bushels in 1956 (Table 10).

Where no fertilizer was used, oats yielded about 12 bushels per acre more on well-drained land than on poorly drained land. When 300 pounds of fertilizer was applied, this difference increased somewhat, averaging about 15 bushels.

Table 10.—Expected Yields of Oats for Selected Rates of Fertilization and Levels of Drainage on Hoytville Soil (Based on the Yield Experience of 95 Farmers in 1955 and 80 in 1956)

Year	Fertilizer used, lbs. per acre[1]	Drainage rating		
		Below average	Average	Above average
		(bushels per acre)		
1955	0	51	58	62
	150	52	58	65
	300	52	58	70
1956	0	40	44	53
	150	42	47	55
	300	44	50	56
Average 1955-56	0	45	51	57
	150	47	53	60
	300	48	54	63

[1]Fertilizer use is expressed in terms of 3-12-12 analysis.

One of the advantages of good drainage is that deviations from planned acreages and sowing dates forced by adverse weather are reduced. This benefit was not measured in this study. It is known, however, that in some cases the desired acreage of oats was not sowed because of weather and soil moisture problems; even above average drainage may be inadequate to control moisture conditions under some circumstances.

From the economic standpoint, use of fertilizer on oats could not be justified by the increase in yield of oats if all of the fertilizer application was charged to the oats. Even on well-drained land, the in-

crease (6 bushels) was worth less than the cost of the fertilizer (6 bushels at 65¢ = $3.90; 300 lbs fertilizer at 2 ½¢ = $7.50). In some cases, use of fertilizer probably could be justified by improvement in the yield of grass or clover seeded in the oats.

WHEAT

While not all the farmers who wanted to sow wheat in the fall of 1954 were able to do so, those who did get it sowed were, on the average, favored with good yields. On some farms, wheat was sowed on land prepared by plowing meadow or small grain stubble. This reduced the risk of bad weather interfering with wheat sowing after soybeans. Sorting the farms into groups on the basis of method of preparing seedbed for wheat indicated little difference in yields from the two methods. Wheat sowed in a plowed seedbed averaged 38 bushels per acre in 1955 compared to 35 bushels for a disced seedbed, but the latter averaged 25 days later in date of sowing. In 1956, the difference in yield was again about 3 bushels[7] although the difference in average date of sowing was only 11 days. Average drainage rating was the same for both groups of farms.

Fertilizer was used more commonly and in larger amounts on wheat than on any other crop. Fertilizer was used on wheat on about

[7]Yield differences are not significant at the five percent level.

Table 11.—Expected Yields of Wheat for Selected Rates of Fertilization and Levels of Drainage on Hoytville Soil (Based on the Yield Experience of 87 Farmers in 1955 and 96 in 1956)

Year	Fertilizer used, lbs. per acre[1]	Drainage rating		
		Below average	Average	Above average
			(bushels per acre)	
1955	200	33	34	37
	350	34	35	38
	500	36	37	40
1956	200	27	31	35
	350	31	33	36
	500	34	35	37
Average 1955-56	200	30	32	36
	350	33	34	37
	500	35	36	39

[1]Fertilizer use is expressed in terms of 3-12-12 analysis.

97 percent of the farms in quantities ranging from 100 to 750 pounds per acre. The average rate was 375 pounds per acre or about 15 percent heavier than the average rate of use on corn. About three-fourths of the fertilizer for wheat was applied with the seed in the fall, with the balance being applied as top-dressing in the spring. Response to the first 200 pounds of fertilizer could not be determined by this study because only a few operators applied no fertilizer to wheat.

On poorly drained land, 500 pounds of fertilizer on wheat yielded 5 bushels per acre more than a 200-pound application. But on above average drained land, the extra fertilizer raised yields only 3 bushels.

Where a minimum application of fertilizer was used, well-drained land yielded six bushels per acre more wheat than poorly drained land. Where the fertilizer application was 500 pounds per acre, the apparent difference due to drainage was only 4 bushels.

This pattern of yield response to drainage and fertilizer is the reverse of that found for other grains. However, it should be recognized that different cultural practices and responses are associated with wheat, depending in part on the degree of drainage. Method of seedbed preparation, time of sowing, degree of winter killing, fertilizer applications in fall and spring, and other factors which may be related to drainage influenced the yields of wheat reported by farmers in this study. The resulting variation prevents any definite conclusions about the relationship of drainage, fertilizer and yields of wheat.

The effect of drainage and fertilization on hay yields could not be analyzed in this study because only a few farmers had sufficiently accurate data on yields of meadow crops. Fertilization of clover and alfalfa was not commonly practiced. Drainage was installed principally to benefit the grain crops, not the meadows. In fact, many farmers felt that the meadows, rather than being a crop in themselves, were merely a step toward a bigger corn crop.

ECONOMICS OF DRAINAGE

Provision of good drainage by means of tile, surface drains and land leveling is a long-term investment. The profitability of this investment can properly be discussed only for the cropping program that will be in effect during the useful life of the drainage system.

The proportion of crops raised on Hoytville soil closely approximated a combination of two cropping programs—a four-year rotation of corn, soybeans, oats and meadow and a three-year rotation of corn, soybeans and wheat, with a green manure crop inter-seeded in the wheat. These rotations represent the extremes of cultural intensity

which were practiced on Hoytville soil. Few farmers had more than one-fourth of their cropland in meadow each year, and very few raised continuous grain crops unless green manure crops were used in the rotation.

Yields of grain crops for various drainage ratings are summarized in Table 12. The increase in the individual yields resulting from improvement in drainage was valued from $7.60 to $15.60 per acre. For

Table 12.—Crop Yields[1] for Various Drainage Ratings and Value of Increases in Yields Due to Improved Drainage, Hoytville Soil

Crop	Drainage rating 1	2	3	Increase in yield (drainage 3 over 1)	Price per bu.	Value of increase per acre
Corn	61	66	74	13 bu.	$1.20	$15.60
Soybeans	25	28	32	7 bu.	2.20	15.40
Oats	47	53	60	13 bu.	.65	8.45
Wheat	33	34	37	4 bu.	1.90	7.60

[1]Based on the following applications of fertilizer per acre: corn, 220 pounds; oats, 150; and wheat, 350 pounds.

a 4-year rotation of corn, soybeans, oats and meadow, the average annual value of increase in yield would be about $9.80 per acre. But for a 3-year corn-soybeans-wheat rotation, the increase in yield would be worth about $12.80 per acre annually.

On a tenant-operated farm, only half of the increase in yield normally goes to the landlord. Depreciation of the investment over the period of expected life must be met from the landlord's share. The amount of investment in drainage systems which the landlord could justify economically was computed by the following formula:

$$\text{Justifiable additional investment in drainage systems per acre} = \frac{\text{Landlord's share of annual increase in value of crops per acre} - \frac{\text{Additional investment per acre}}{\text{Average life of drainage system}}}{\text{Interest rate used for capitalization}}$$

The average life of a tile drainage system was estimated at 40 years. If a shorter or longer life were assumed, the justifiable investment would be different.

Table 13 shows that a landlord owning poorly drained land could afford to invest from $75 to $116 per acre (depending on the rate used for capitalization) in additional drainage installations if the land were farmed under an intensive grain cropping program. If the cropping program included a smaller proportion of high value crops, the justifiable investment might be as low as $58. If an owner-operator chose to capitalize all of the increase in income or if a landlord chose to capitalize his added returns from being able to attract a better tenant, the justifiable investment might be increased.

Table 13.—Economically Justifiable Investment in Additional Drainage for Typical Rotations and Capitalization Rates, Hoytville Soil

Rotation	Increase in value of crops per acre		Economically justifiable investment in tile drainage per acre for different rates of capitalization			
	Total	Landlord's share	3%	4%	5%	6%
C Sb O M	$ 9.80	$4.90	$ 89	$75	$65	$58
C Sb W (gm)	12.80	6.40	116	98	85	75

All farms in this study had some tile but none had perfect or optimum drainage systems. The amount of tile or the extent of other drainage inputs was not measured or counted so it is impossible to state the exact amount of tile drainage installations that were required for a given drainage rating. Similarly, it is impossible to determine the response in yield or value of crops resulting from installation of drainage systems except by experimentation[8].

Reduction in risk and in variability of income may be factors in the decision to invest in more drainage. Also to be considered is the opportunity which improved drainage presents to expand total crop production by using fertilizer.

[8]A complete tile drainage system costs approximately $125 to $140 per acre where typical length of main lines is needed. Surface drainage may involve up to $10 per acre for land leveling and construction of waterways. It may be assumed that these inputs, plus good management in returning crop residues and avoiding compaction, would result in good (#3) drainage, but what combination or amounts of inputs results in #1 or #2 drainage is not known.

YIELDS AND PROFITS FOR DIFFERENT ROTATIONS

Grain Yields. The effects of different cropping programs on yields are shown in Table 14. Yields of soybeans, oats, and wheat were approximately the same regardless of the crop rotation followed. But corn yields were slightly higher when a mature meadow was plowed under instead of a green manure crop.

Yields for each cropping program were adjusted for variations in drainage and fertilizer applications to make production figures comparable. Figures used for adjusting degree of drainage and fertilizer applications to the same level for each of the six cropping patterns were taken from Tables 6, 9, 10, and 11. Yields for the different crop combinations in Table 16 are for a 2.1 drainage rating and the following applications of fertilizer in terms of a 3-12-12 analysis or its equivalent:

Table 14.—Grain Yields for Different Cropping Programs on Hoytville Soil, 1955-56

Number of cases	Cropping program[1]				Average number of bushels per acre[3]			
	Corn and soybeans	Oats and wheat	Meadow	Green manure[2]	Corn	Soybeans	Oats	Wheat
	percent	percent	percent	percent				
16	66	32	2	18	65	28	54	36
16	63	25	12	18	72	31	61	34
16	51	33	16	14	70	31	54	35
11	60	20	20	7	69	28	56	35
20	50	25	25	7	73	28	52	33
11	40	30	30	8	70	29	51	38

[1]Stated in percentage of rotated land.
[2]Did not occupy land alone; green manure grown with small grain crop.
[3]Adjusted to same drainage level and fertilizer applications.

300 pounds per acre for corn; 130 pounds for oats; and 350 pounds per acre for wheat.

Sorts based on specific rotations could not be made because of the small proportion of farmers who actually followed a definite rotation. Reasons given for not establishing a certain sequence of crops included variations in relative profits from different crops, unfavorable weather and government control programs for corn and wheat. In some years, the planned acreage of wheat and oats was not raised because these crops could not be planted at the proper time. Also, on the poorly

drained land, soybeans were often substituted for corn in seasons when the soil was too wet to plant corn at the proper time.

Yields in Table 14 were determined for the cropping programs used in 1955 and 1956. Analysis of yields as affected by percentage of the land in meadows in previous years and percentage in green manure in the current year showed the same relationship between yields and cropping programs as given in Table 14. Hay yields could not be determined for different cropping patterns because many farmers did not harvest this crop.

Profits per Acre. Yields used for calculating gross receipts are shown in Table 15. Grain yields are based on the production figures reported in Table 14. Hay yields represent the average amount harvested from two cuttings of alfalfa-grass mixture.

Profits were calculated for different rotations and ways of handling the meadow crops (Table 16). Rotations numbered 1 to 5 approximate the cropping programs found on most of the farms studied.

Grain prices used in calculating gross receipts were Ohio averages for the period 1955-59. Specific prices were as follows: corn, $1.20

Table 15.—Yields Used for Calculating Profits for Different Rotations on Hoytville Soil

Rotation[1]	1.	C	Sb	W (GM)				
Yield[2]		65	28	35				
Rotation	2.	C	Sb	O (GM)	C	Sb	W	M
Yield		70	28	54	65	28	35	2.8
Rotation	3.	C	C	Sb	W	M		
Yield		70	67	28	35	2.8		
Rotation	4.	C	Sb	Sb	W	M		
Yield		70	28	28	35	2.8		
Rotation	5.	C	Sb	W	M			
Yield		73	28	35	2.8			
Rotation	6.	C	C	O	M			
Yield		73	70	54	2.8			
Rotation	7.	C	O	M				
Yield		73	54	2.8				
Rotation	8.	C	O	M	M			
Yield		73	54	2.8	2.8			

[1]C=corn; Sb=soybeans; O=oats; W=wheat; M=meadow; (GM)=green manure crop sowed in oats and wheat and plowed under the following spring.

[2]Grain yields in bushels; hay yields in tons per acre.

per bushel; soybeans, $2.20; oats, $.65; and wheat, $1.90 per bushel. Total charges for raising each crop were determined on the basis of local tillage and harvesting methods and average costs of farm supplies from 1955-59. Estimated costs of producing the various crops were as follows: first-year corn, $57.25 per acre; second-year corn, $62.25 ($5.00 additional charge for fertilizer); soybeans, $40.00; oats, $40.25; wheat, $48.10; meadow not harvested, $20.00 when seeded in wheat and $18.50 when seeded with oats; first-year meadow harvested twice and sold, $60.50 when seeded in wheat and $59.00 when seeded with oats; and second-year meadow harvested twice and sold, $54.00 an acre. Cost of establishing green manure was figured at $2.50 an acre when seeded with oats and $4.00 an acre when seeded with wheat.

Table 16.—Calculated Profits Per Acre for Different Rotations and Uses of Meadow Crops on Hoytville Soil

Disposition of sod crop		Rotation[1]	Average annual profit per acre
Plowed under (no top growth removed as hay or pasture)	1.	C Sb W (GM)	$18.92
	2.	C Sb O (GM) C Sb W M	11.64
	3.	C C Sb W M	12.98
	4.	C Sb Sb W M	13.67
	5.	C Sb W M	12.59
	6.	C C O M	7.11
	7.	C O M	2.23
	8.	C O M M	—2.07
Hay harvested and sold for $22.00 a ton at farm	2.	C Sb O (GM) C Sb W M	$14.65
	3	C C Sb W M	17.20
	4.	C Sb Sb W M	17.89
	5.	C Sb W M	17.86
	6.	C C O M	12.39
	7.	C O M	9.27
	8.	C O M M	8.85
Hay harvested and sold for $15.00 a ton at farm	2.	C Sb O (GM) C Sb W M	$11.85
	3.	C C Sb W M	13.28
	4.	C Sb Sb W M	13.97
	5.	C Sb W M	12.96
	6.	C C O M	7.49
	7.	C O M	2.73
	8.	C O M M	— .95

[1]C=corn; Sb=soybeans; O=oats; W=wheat; M=meadow; (GM)=green manure crop sowed in oats and wheat and plowed under the following spring.

These figures are based on paying all labor $1.50 an hour. All of the fertilizer and manure were charged against the crop to which they were applied. This procedure was possible because all profits were calculated on a rotation basis. Charges for each crop are itemized in Appendix A.

Net income figures show that the most profitable rotation was corn, soybeans and wheat with a green manure crop grown in the wheat and plowed under the following spring for corn. This cropping program was more profitable than rotations in which meadow crops were harvested as hay and sold for $22.00 a ton at the farm.

Rotations numbered 3, 4 and 5 gave about the same profits per acre when disposition of the meadow crops was the same. These rotations had no oats and only 20 to 25 percent of the cropland was used for meadow. Soybeans produced about the same profit per acre as corn. Rotation 2, which contained some oats, was not quite as profitable as rotations 3, 4 and 5, which used wheat for the small grain crop.

Rotations numbered 6, 7 and 8 were at the bottom of the list from the standpoint of profitability. These rotations would have produced higher profits except that a 35-bushel wheat yield could not be obtained when this crop followed corn because of late and uncertain seeding. Net income figures show that a rotation of corn, corn, wheat and meadow would be about as profitable as rotations 3, 4 and 5 if 35 bushels of wheat could be raised per acre. On an acre basis, oats produced a gross return of only $35.10 compared with $66.50 for a normal yield of wheat. However, this study showed that only about two percent of the farmers sowed wheat after corn. About 60 percent sowed wheat after soybeans, 30 percent sowed wheat after oats or wheat, and 8 percent sowed wheat after other crops. Rotations 7 and 8 would not be as profitable as the others even if wheat were substituted for oats unless hay could be sold for considerably more than $22.00 a ton.

When hay was harvested and sold for $15.00 a ton, net income was about the same as when no meadow growth was harvested as hay or pasture. However, harvesting hay would have this advantage over plowing all of the meadow growth under: it would increase the total amount of income the farmer would receive for his labor because his own labor could be used to harvest the hay at the $1.50 per hour rate used in the above calculations.

Other calculations showed that the price of hay would have to be about $27.00 a ton at the farm to make a rotation of corn, wheat, and two years of meadow as profitable as corn, soybeans, wheat and

one year of meadow. This conclusion is based on a hay yield of 2.8 tons per acre and a wheat yield of 35 bushels per acre when sowed after a crop of corn. In determining profits from hay, consideration also should be given to the fact that occasionally some hay is lost in harvesting because of unfavorable weather.

APPENDIX

Appendix A.—Estimated Costs Used in Calculating Profits in Table 16

	Production costs per acre						
						Hay sold	
Charges	Corn (first-year)	Soybeans	Oats	Wheat	Meadow plowed under[1]	First year meadow	Second year meadow
Labor[2]	$10.75	$ 7.25	$ 5.50	$ 6.00	$ .50	$11.50	$11.00
Machinery	16.00	12.75	10.25	11.25	1.00	16.25	15.25
Seed	2.00	3.25	3.00	5.00	3.50	5.00	.00
Fertilizer and manure[3]	8.50	.00	3.25	8.75	.00	7.00[4]	7.00[4]
Land	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Storage	5.00	1.75	3.25	2.10	.00	5.75	5.75
Total	$57.25[5]	$40.00	$40.25	$48.10	$20.00[6]	$60.50[7]	$54.00

[1]Cost of establishing green manure was figured at $2.50 an acre when seeded with oats and $4.00 an acre when seeded with wheat. (Seed was $2.50; seeding in wheat required a charge of $.50 an acre for labor and $1.00 for tractor and machinery).

[2]Figured at $1.50 an hour.

[3]All charged against crop to which it was applied.

[4]Charge for mineral nutrients removed.

[5]Second-year corn figured at $62.25 which includes $5.00 additional fertilizer.

[6]Cost when seeded in wheat; figured at $18.50 when seeded in oats.

[7]Cost when seeded in wheat; figured at $59.00 when seeded in oats

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